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Internet Tools for Facilitating Scientific Inquiry

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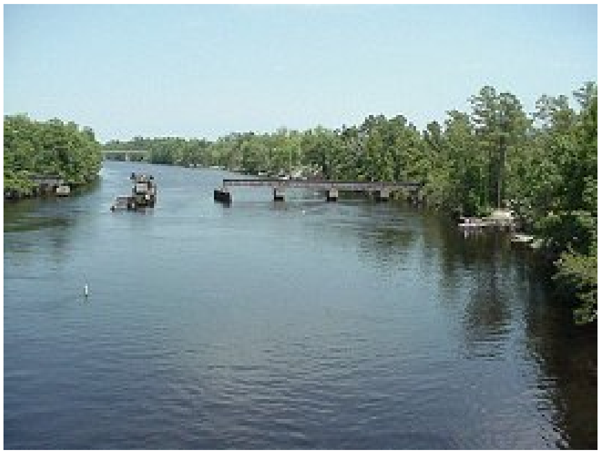
Abstract

Effective use of the Internet in K-12 science education may have little or nothing to do with surfing the web. In this paper we examine another way of using the Internet in inquiry-based middle school science classrooms--using Internet resources that provide relevant databases along with useful and engaging tools for exploring and interpreting the data. Specifically, in this paper we discuss the educational applications of two Internet utilities that use water quality data to facilitate teachers and students developing various science process skills.

Contrary to a common misconception, effective use of the Internet in K-12 science education has little or nothing to do with surfing the web. Quite the contrary, the most productive and effective science education applications of the Internet involve teachers and students accessing specific pre-selected sites in order to accomplish pre-determined objectives (Huber and Harriett, 1998; Moore and Huber, in press; Watson, 1999). This is not to imply, however, that the Internet should not be used to support relatively open-ended inquiry-based instructional approaches. Such approaches are essential because students learn only by constructing their own conceptualizations -- that is by making their own meaningful connections between what they already know and the new information they encounter (Martin 2000). Fitzgerald, Buie &

"...the most productive and effective science education applications of the Internet involve teachers and students accessing specific pre-selected sites in order to accomplish pre-determined objectives."



Cuales (1998) draw upon Tufte's (1983) seminal work on the visual display of quantitative information in a discussion of how "elegant" and "transparent" interfaces of computerized displays of quantitative graphics can facilitate users in drawing such personal meaning from the displayed information. In a similar vein, Huber and Harriett (1998) describe the following three inquiry-based types of Internet-supported science instruction, all of which are constructivist oriented:

(1) the use of daily access sites, which are comparable to "newspaper in the classroom" programs;

(2) virtual field trips; and

(3) Internet-based projects.

All of these approaches, especially Internet-based projects, are highly compatible with the goals of constructivist-oriented inquiry-based science instruction (Moore and Huber, in press).

In this paper we examine another way of using the Internet in inquiry-based middle school science classrooms--using Internet resources that provide relevant databases along with useful and engaging tools for exploring and interpreting the data. Specifically, in this paper we discuss the educational applications of two Internet utilities that use water quality data to facilitate teachers and students developing various science process skills. The resources are particularly useful in helping students build strengths in the areas of

(1) manipulating, visualizing and interpreting data;

(2) making and testing scientific hypotheses; and

(3) practicing scientific inquiry.

Each of the Internet utilities reviewed in this paper provides access to a substantial database. "Water on the Web" (http://wow.nrri.umn.edu/wow/index.html) contains data on lakes and the "River Run" (http://www.uncwil.edu/riverrun/) contains data on rivers. Additionally, each utility offers powerful data manipulation and processing tools appropriate for use by middle school students. The tools allow teachers and students to generate animated graphic displays showing relationships among water quality parameters through space and time. These displays use line graphs and color gradients to display data on multiple water quality parameters while also animating the graphs, displaying a sequential series of graphs, in order to show changes through time. The animated graphs function much like a computerized enhanced version of the "small multiples" described by Tufte (1983; 1990) as highly effective means of displaying complex, multi-variable, quantitative information.

Water on the Web
(http://wow.nrri.umn.edu/wow/index.html)

River Run
(http://www.uncwil.edu/riverrun/)

Among the strengths of these utilities is the fact that they provide Internet-based tools supportive of inquiry-based science instruction. Although there is no universally accepted concise definition of the term "inquiry-based science instruction," there is broad general consensus regarding the fundamental nature and value of inquiry-based instruction. Strong support for inquiry-based instruction has been articulated by the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), the National Commission on Science Education Standards and Assessment (NCSESA), and the National Research Council (NRC). The nature of inquiry-based instruction is perhaps most clearly described in the "vision" of the National Science Education Standards, published under the auspices of the National Research Council (1996). As envisioned in the Standards, inquiry-based teachers function as facilitators and supporters of student learning rather than as disseminators of knowledge. The vision of the Standards is one of dynamic learning communities working within enriched learning environments supported by an educational system that has been overhauled to provide the support those communities will need. Within these learning communities, students are actively engaged in cooperative, inquiry-driven, experiential, "hands-on and minds-on" learning activities that emphasize problem solving and creative thinking. Through these experiences, curriculum goals and objectives are met as students construct meaningful, broadly applicable, well-structured, information-rich knowledge, skills, abilities, and affective domain attributes. Within this setting, the Standards recognize the symbiotic nature of science and technology and science- and technology- education. The response to the Standards has been strong and supportive (Moore and Huber, in press; Loucks-Horsley, 1998; Zeidler, 1998; Bereiter, Scardamalia, Cassells, and Hewitt, 1997; Collins, 1997; Mergendoller, 1997; Bybee and Champagne 1995; Bybee 1995; Pratt 1995; Riechard, 1994).

To Page 2 of 5

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| **Table of Contents** | **Review Board** | **Resources** | **Archive** |

| **Table of Contents** | **About Meridian** | **Resources** | **Archive** |

MERIDIAN

Internet Tools for Scientific Inquiry

"We have found the type of Internet resources reviewed in this paper to be useful for facilitating the delivery of the type of inquiry-based instruction envisioned in the National Science Education Standards. "

Students as Scientists Project

We have found the type of Internet resources reviewed in this paper to be useful for facilitating the delivery of the type of inquiry-based instruction envisioned in the National Science Education Standards. The resources provide access to outstanding databases that are relevant to studies of water quality along with engaging and useful tools for exploring that data. Students using these Internet resources become engaged in inquiries that promote their development of scientific-, computer-, and graphic-literacy. Additionally, the value of these tools can be enhanced by integrating their use in the classroom with other compatible Internet-based educational resources. For example one of the resources discussed in this paper, the "River Run Data Visualization Tool," can be readily and seamlessly integrated with another Internet-based educational program, the "Students as Scientists Project" (http://smec.uncwil.edu/GLAXO/SAS/index.htm - best viewed using Internet Explorer 4.0 or higher). When used in concert, these two programs provide students with experience in a wide range of scientific activities including obtaining water samples, analyzing those samples, publishing and processing their data using the Internet and Excel, and generating and interpreting literally hundreds of graphs displaying comparable data to their own (though more valid and reliable than data drawn from student analyses alone).

Water on the Web (WOW) provides water quality data collected from remote underwater sampling stations placed in five Minnesota lakes (http://wow.nrri.umn.edu/wow/index.html), which continuously sample and analyze water from different depths in the lakes. "Data visualization tools," accessible from the WOW web site, allow students to see and explore relationships among the data points that would probably be lost to them were the data merely displayed as matrixes of numbers. Most importantly, students can, with a few points and clicks, change parameters defining the dynamic graphic displays. Thus, the utilities provide simple and engaging mediums for open exploration and powerful effective tools for hypothesis testing. For example, in an inquiry-based classroom a teacher might direct students to use the "color mapper" data visualization tool to explore lake stratifications. Under this scenario, the teacher might have students define the parameters so that water temperature is color-graphed and dissolved oxygen is shown with a line graph (note that different students could be looking at data from various lakes and at various time frames in this example). Through the teacher-guided inquiry, students should quickly discover how sharp gradients in temperature and dissolved oxygen define the epilimnion strata at the surface of lakes. Students could then form hypotheses predicting how other variables might behave around this boundary and ultimately, they could change system settings and "run" animations to test their hypotheses. Data visualization tools within WOW are also well suited for presenting clear pictures of various complex and interesting phenomena and events that occur within lake ecosystems. For example, because water is at its most dense at 4 degreesC, the water at the bottom of a deep lake remains at 4 degrees C year round. Consequently, as surface waters cool to this temperature in the autumn and warm in the spring, the waters of a deep lake may "turn over" twice a year. The data visualization tool is an ideal resource for exploring and displaying the important impacts of this dynamic event.

Water on the Web (WOW)
http://wow.nrri.umn.edu/wow/index.html

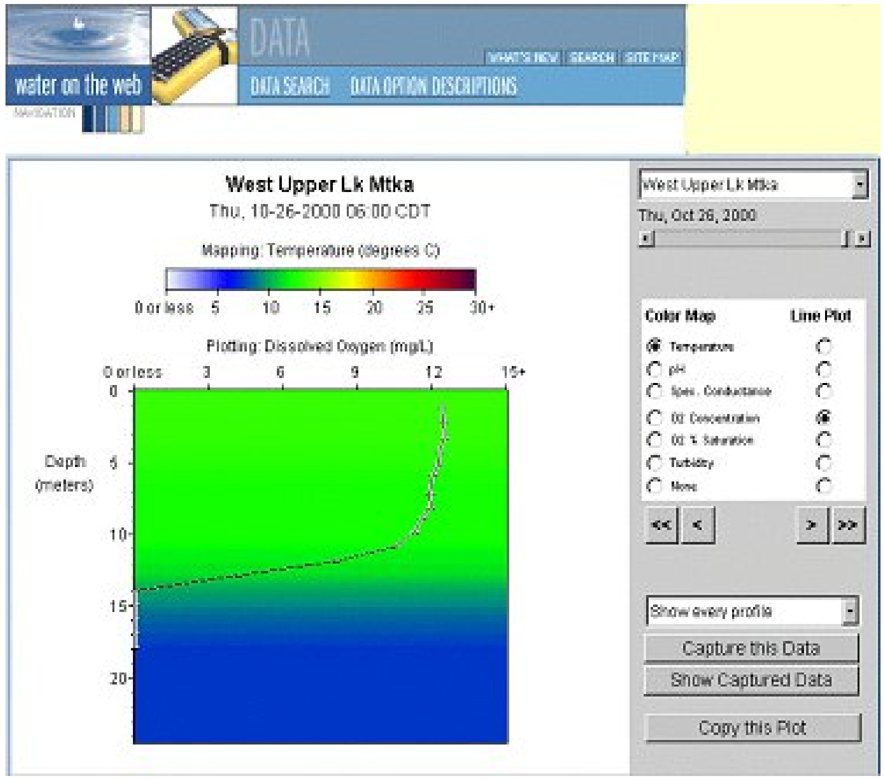

Figure 1. Lake stratification from *Water on the Web*.

[*River Run Resource*](http://www.uncwil.edu/riverrun/)
http://www.uncwil.edu/riverrun/

The WOW web site offers several additional powerful utilities that could be useful in an inquiry-driven middle school science classroom. The site also provides teacher- and student-oriented lesson plans to facilitate teachers in effectively implementing these resources.

The River Run Resource (http://www.uncwil.edu/riverrun/) offers two main interactive data displays, the ARCVIEW Internet Map Server (IMS) and the Data Visualization Tool (DVT). The IMS in River Run is used for displaying and querying maps of the Lower Cape Fear River drainage basin. The maps are interactive, permitting the user to zoom in and out of the maps with different amounts of detail being presented at different spatial scales. This tool gives the user the power to link databases and maps to create dynamic displays. Global Information Service tools such as the IMS have been demonstrated as effective support structures to facilitate students in conducting original research and spatial analysis (Alibrandi, 1998).

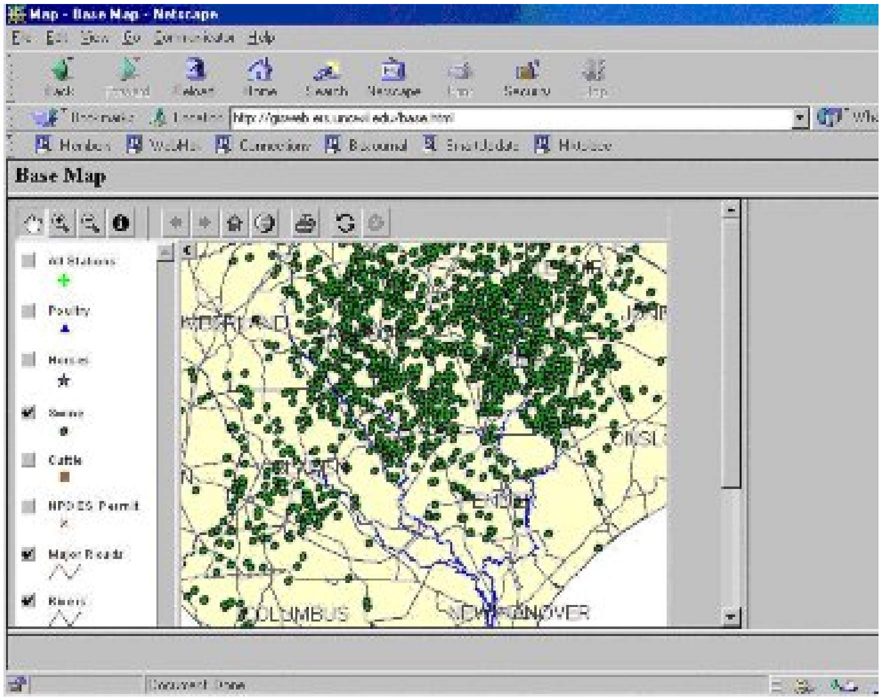

Figure 2 Example of an IMS from the *Riverrun* Website.

The Data Visualization Tool is similar to the color mapper for lake data described above, with the exception that the X-axis of the displayed graphs is analogous to the Y-axis in the lake data. That is, in the lake graphs the vertical dimension is used to map lake depth whereas in the river graphs the horizontal axis of the graph maps the flow of the river (from upstream on the left to downstream on the right).

To Page 3 of 5

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| Table of Contents | Review Board | Resources | Archive |

MERIDIAN

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"One of the strengths of the River Run Data Visualization Tool is that it provides numerous opportunities for students to discover and explore extremely interesting ecological events, which tend to stand out when the data is graphically displayed."

One of the strengths of the River Run Data Visualization Tool is that it provides numerous opportunities for students to discover and explore extremely interesting ecological events, which tend to stand out when the data is graphically displayed. These provocative anomalies are abundant because the river systems from which the data are drawn have experienced numerous highly noteworthy events during the years over which the data are collected. Specifically, the River Run resource provides data and utilities for exploring data on the water quality of the Cape Fear River and the Northeast Cape Fear River from 1995 to 2000. During these years these river systems experienced a major poultry farm spill, several ruptures of hog waste lagoons, five hurricanes, and a 500-year flood. Consequently, when water quality data on the rivers are explored using the data visualization tool, conspicuous spikes in line graphs and flashes of color on the color mapper pop up frequently. These anomalies invite students to stop the animations, form hypotheses, reset parameters, and rerun the animations to test their hypotheses. For example, under the DVT default settings for September 1998, at the NAV site, the effects of Hurricane Bonnie on four water quality parameters can be dramatically seen (Figure 3). The large spike in fecal coliform bacteria can be attributed to the shut down of the City of Wilmington's north side sewage treatment plant when the back-up power generators failed resulting in untreated human sewage being dumped directly into the Cape Fear River. By resetting the parameters, students can easily determine the impact of Hurricane Bonnie on nine additional parameters at the NAV site or any of the other 15 sampling sites.

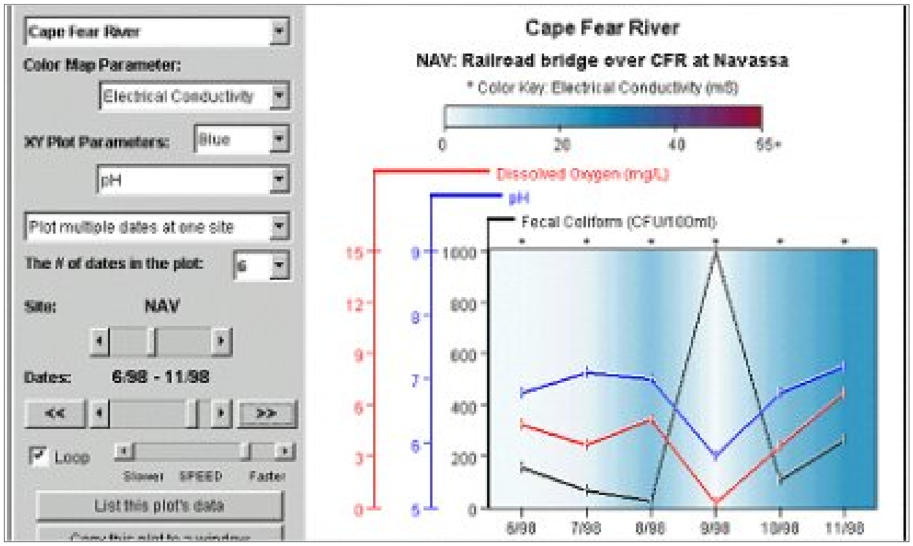

Figure 3. Effects of Hurricane Bonnie on four water quality parameters.

These findings suggest several hypotheses that could be explored further using the DVT and/or other resources available in middle school classrooms. For instance, why did the dissolved oxygen drop to almost zero shortly after Hurricane Bonnie? Additionally, when conductivity (an indirect measure of the salinity of the water) is graphed, there appears to have been unusually low conductivity after the storm. With the aid of probing and guiding questions from their teacher, students might reasonably predict that the findings shown in the data animations occurred as the result of increase in stream flow at the NAV test site. Runoff from flooded agricultural areas caused increases in turbidity and nutrients including nitrogen compounds and phosphorus. Meanwhile, the tremendous increase in the flow of water from rains associated with the hurricane simply diluted and washed the normally salty water out to sea and thereby decreasing the conductivity.

Interpretations such as those made above could be further tested using the DVT and/or with other appropriate resources (such as newspaper records of floods or animal waste spills). Regardless of the direction students and teachers take when exploring such anomalies, the animated color-coded graphics are an ideal tool for making the data come alive--the graphics leave no doubt about the fact that something interesting happened around the NAV testing station in September of 1998! Additionally the DVT provides a good resource for exploring such anomalies using tools that hold much promise for promoting students' ongoing development of scientific-, computer- and graphic literacy.

The WOW and River Run websites provide the middle school science teacher with two powerful tools for assisting students in constructing meaning from environmental events. Using these utilities the teacher becomes a facilitator of inquiry guiding the students as they select parameters to be observed and noting the changes over time.

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Internet Tools for Scientific Inquiry

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Richard A. Huber is an associate professor of science education at the University of North Carolina in Wilmington. He holds a Masters Degree and Ph.D. in Science Education from the University of Iowa. His undergraduate degree is in Biology with a minor in Chemistry. Dr. Huber has eight years of public school teaching experience and ten years of central office administration. Dr. Huber received UNCW's Distinguished Teaching Professor award in 1999 and a UNCW Innovations in Technology Award in 2000. He has served as the P.I. on 14 externally funded projects totaling over $950,000.

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Page 1 of 5

M E R I D I A N

Internet Tools for Scientific Inquiry

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Daily access sites:

http://www.weather.com/

http://www.epa.gov/airnow/

Cyber Field Trip sites:

http://quest.arc.nasa.gov/mars/photos/index.html

http://www.exploratorium.edu/

http://oposite.stsci.edu/pubinfo/pictures.html

Internet Based Projects:

http://WWW.Globe.gov/

http://www.learner.org/jnorth/

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To Page 5 of 5

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